

Appendix F

The United States Forest Service Three Level Stability Analysis Concept



1B. Introduction to the Three-Level Stability Analysis Concept

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1B.1 Role of Analysis in the Decision-Making Process

Slope stability specialists must be able to predict how land management activities—such as logging operations and road construction—will impact land stability. This assessment is useful to the land manager, usually a district ranger, in evaluating the level of the potential watershed impacts among various alternatives. The land manager usually has no professional background in evaluating slope stability and therefore must rely on the knowledge, skills, and abilities of the district earth scientists and engineers or specialists from a zone office or forest headquarters. This predictive capability is the fundamental principle of the three-level stability analysis concept. By using this method the specialist will be successful in assisting the decision maker.

Determining which technique to use can be confusing for the specialist who does not routinely perform slope stability analyses. Effective communication between the specialist and the person requesting the analysis can minimize this confusion. With effective communication there is an understanding of the basic reasons for the work. Effective communication also leads to a slope stability analysis matched to the level and complexity of the problem and avoids analysis simply for its own sake. The common result of ineffective communication and inappropriate analysis is that the requester will not ask for this service in the future.

It is important for the specialist to understand that the data gathered will be used to define slope conditions. Moreover, he or she should know that the analysis is being made to model the current land stability conditions and potential impacts as a result of excavation, logging, construction, damming, or other management activities. Also, the engineer or scientist should know how the results fit into a rational decision-making framework. Considering the wide range of land management decisions requiring a supporting slope stability evaluation, it is important that the prudent specialist adapt the investigation and analysis to the decision being made.

1B.2 Land Management Decisions Requiring Stability Input

Many forested lands in the western United States have the potential to be unstable because of geologic and hydrologic conditions and material strength properties. The National Environmental Policy Act (NEPA) of 1969 and the National Forest Management Act (NFMA) of 1976 require that the management of these lands includes stability assessment at all planning levels: resource allocation (forest plan, 10-year scheduling, and timber sale planning), project planning (timber sale environmental assessment and transportation planning), and project development and monitoring

(site stabilization and implementation of the preferred alternative). This requirement has led to the development of the three-level stability analysis concept (Prellwitz et al., 1983; Prellwitz, 1985). Figure 1B.1 is a flowchart of this analysis system.

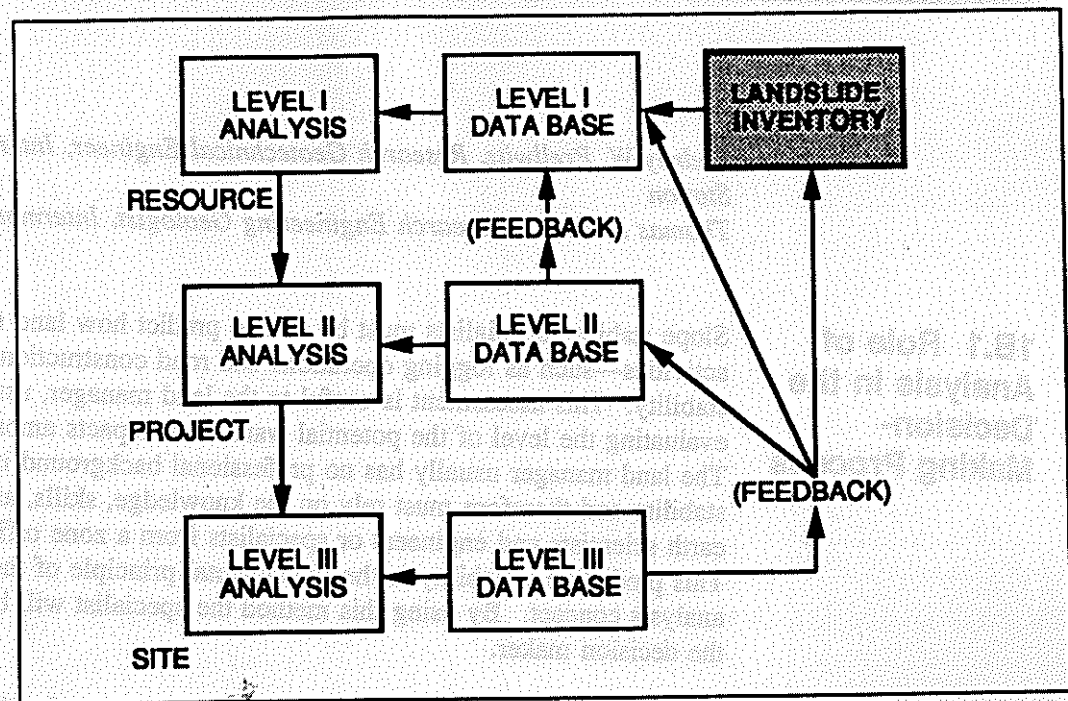


Figure 1B.1.—Slope stability analysis flowchart with the portion which section 1 pertains to highlighted.

The three levels are progressive in scale, detail, complexity, and accuracy. This progression focuses attention on specific problems in a logical order. It also allows the analyzer to draw from the previous analysis and data bases as new data are developed to support the higher analysis levels. At levels I and II, the analysis techniques have a probabilistic version to allow for the determination of parametric values over the areal extent of the analysis. Also, the probabilistic output lends itself well to the decision-making process. A comparison of the combination of slope failure probability with the relative failure consequences eases this process, allowing the manager to base the decision on acceptable risk levels. The deterministic version of the analysis is still necessary to facilitate sensitivity analysis, parametric value evaluation, and back-analysis.

The following levels ensure that suitable investigation and analysis techniques are available for the qualified specialist to provide timely and efficient input to support decisions:

1B.2.1 Level I: Resource Allocation

The types of decisions at this level are made from data gathered at a watershed scale (usually 1:24,000 or greater), and the evaluation of the relative stability assesses hazards involved in the proposed activity. At this level the decision maker determines the resource allocations and where to develop them. The stability assessment usually uses available inventory data in the simplified stability analysis techniques. In most cases, these data are from a geographic information system (GIS), a geologic

resource and conditions data base, or both. Because the stability of the entire land mass is being considered, the analysis techniques must model the failure mode of natural slopes. These failures may be either planar (translational) or circular (rotational) in shape, and the analysis must be able to model both modes. The stability of constructed slopes usually is not evaluated at this level.

1B.2.2 Level II: Project Planning

The next major level of decision making requiring slope stability input occurs in the project planning phase (e.g., timber sale environmental assessment, transportation planning, and road closure planning). Timber-harvest decisions on tree removal and the impacts on the stability of natural slopes include the modeling of tree-removal effects. The two important factors in this analysis are root strength and ground water. The stability of constructed slopes is often more significant than that of natural slopes at the project level; however, a simplistic analysis that estimates the relative stability of the road slope is adequate at this level. Critical locations identified at this level will be considered for level III analysis. A primary difference between the level II and level III analyses is that the latter must allow the analyzer to evaluate many unique site conditions and stabilization measures. The data base used in the level II analysis must be more accurate than that used in level I. Project reconnaissance includes field-developed cross-sections measured at locations critical for this level. Measurements of the field-developed cross-sections are usually at a 1:600 to 1:3,600 scale; therefore, the data collected will be more accurate than that collected for level I, but less accurate than that collected for level III.

1B.2.3 Level III: Site Stabilization

Critical sites recognized during the level II analysis may require a level III analysis if the site cannot be avoided. For example, to gain access to a landing, the district transportation planner lays a proposed road corridor across an inactive landslide. For economic or ecological reasons the district ranger chooses this route. The level II analysis predicts slope stability problems will occur. The next step, then, is to complete a level III analysis to evaluate various stabilization methods—such as buttresses, drainage, retaining walls, or additional excavation—for the site. All options—including the do-nothing alternative—are available for consideration so that the manager can have a perspective of the inherent cost and resource risk of each. The report from this analysis allows the decision maker to compare possible stabilization alternatives and to make a decision based upon relative cost and resource risk.

Section 6 of this guide includes a detailed description of these analyses. Measurements for site stabilization investigations are usually at a 1:120 to 1:600 scale. These measurements and subsequent analysis techniques are more complex than those for levels I and II. This increase in data resolution is necessary to determine existing conditions and to evaluate all possible stabilization alternatives.

1B.3 Stability Analysis Applicable at the Three Levels

There is a danger in fixing a certain analysis method to a certain decision level because there is some overlap in applicability. Consideration of the type of slope (natural or constructed) and the failure mode (translational or rotational) is always important. In a level I decision, stability of large land masses is of primary concern, whereas in level III decisions, stability of specific critical slopes (usually constructed) is the primary focus. In level II the decisions are somewhere between these two levels. The following analysis techniques are the most applicable:

1B.3.1 Level I: Infinite Slope Equation

An explanation of this simple and versatile equation is presented in section 5 of this guide. Although simple, it still does an adequate job of allowing one to model all of the important factors in analyzing the potential translational failures of natural slopes. In addition, the analysis is applicable to rotational characteristics (Prellwitz, 1975; Ristau, 1988). Together with a Monte Carlo simulation technique, this equation is a powerful tool for incorporating spatial variability of input parametric values and the uncertainty of the analyzer in determining what those values are (Hammond et al., 1992).

1B.3.2 Level II: Stability Number Solutions

The infinite slope equation is still applicable to evaluate the impacts of timber harvest on the stability of natural slopes. The analyzer can anticipate changes in two important factors in his or her modeling that might result from the removal of trees: root strength and ground water in response to precipitation changes. To evaluate the relative stability of proposed constructed road cut-and-fill slopes on the natural slopes, two stability number solutions are available:

Critical Height Analysis

A critical height analysis predicts the maximum (critical) height for a stable constructed slope. A computer program using correction factors for subsurface conditions with Chen and Giger's method (1971) is currently under development.

Estimated Factor of Safety

This type of analysis predicts the factor of safety against failure that one might expect from a level III analysis of a simple constructed slope. This type of analysis lends itself well to a probabilistic approach using a Monte Carlo simulation similar to the one used for the infinite slope equation. This analysis method may be applicable to supporting level I decisions when the potential of road-related failures is a primary concern. A computer program using subsurface correction factors coupled with the Cousins method (Cousins, 1978) is in development.

1B.3.3 Level III: Method of Slices

At this level of decision making, the specialist must be able to model many unique critical site conditions and stabilization measure characteristics. This requires a more complex analysis technique than those used in levels I and II. The most common technique is to divide the potential failure mass into a series of slices and model the individual slice forces—first individually and then collectively—in a summation process to arrive at a prediction of the overall potential for failure. Several “method-of-slices” solution techniques are available, all having a common soil mechanics base but differing in the manner in which they are satisfied, the more complex and more difficult the analysis becomes. The computer program XSTABL (XSTABL Ver. 4.1 1992) developed by Sharma for Level III analysis uses the simplified Bishop method for rotational failures and the simplified Janbu method for failures of any general shape. These methods are sufficiently accurate for most forest road applications. Sharma (1992) gives a comparison of these methods to other methods of slices.

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